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of Engineers
New England Division

Drought Contingency Plan

July 1992

Tully Lake, Royalston, Massachusetts

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The Massachusetts Department of Environmental Protection (DEP) withdrew its support as a sponsor for the drought contingency plan at Tully Lake. Upon close examination of towns in the vicinity of this project, Massachusetts DEP could not find any interest in utilizing Tully Lake as a source of emergency water supply. Therefore, this plan is not implementable.

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SUMMARY

In letter, dated January 7, 1992 (copy attached), the Massachusetts Department of Environmental Protection (DEP) withdrew its support as a sponsor for the drought contingency plan at Tully Lake. Upon close examination of towns in the vicinity of this project, the Massachusetts DEP could not find any interest in utilizing Tully Lake as a source of emergency water supply. The Massachusetts DEP is, therefore, not interested in entering into a contract with the Corps.

Since the drought contingency plan was nearing completion at the time of the DEP withdrawal, the comprehensive plan is presented herein for informational purposes only.

DROUGHT CONTINGENCY STORAGE FOR EMERGENCY WATER SUPPLY PURPOSES AT TULLY LAKE IS NOT IMPLEMENTABLE

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Protection

William F. Weld
Governor
Daniel S. Greenbaum
Commissioner

January 7, 1992

Mr. Richard D. Reardon
Corps of Engineers
424 Trapelo Rd.
Waltham, MA. 02254-9149

Dear Mr. Reardon:

I am responding to your letter of December 31, 1991. The Department of Environmental Protection is not interested in entering into a contract with the Corps for the purpose of utilizing Tully Lake as a source of emergency water supply. This decision is based on the work done by your staff and members of DEP staff which determined that the communities near Tully Lake were not interested in the opportunity. Without the local interest, the Department has no role to play.

I thank you for your time and effort on this matter.

Sincerely,

David Y. Terry, Director
Division of Water Supply

cc: Andrew Gottlieb, DWS
John Desmond, CERO
Kurt Boisjollie, WERO

TULLY LAKE
DROUGHT CONTINGENCY PLAN

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TULLY LAKE
DROUGHT CONTINGENCY PLAN

1. PURPOSE AND SCOPE

The purpose of this report was to develop and set forth an emergency drought contingency storage plan for operation of Tully Lake that would identify how the New England Division could render assistance to the Commonwealth of Massachusetts during State-declared drought emergencies affecting domestic, municipal, and industrial water supplies. The scope of this report was not to address the feasibility of providing a permanent water supply pool at Tully Lake, but rather to use a temporary short term pool during a drought emergency. The scope was to identify possible modifications to project regulations within current administrative and legislative constraints. Assistance will be provided through flexibility of regulation and use of existing storage at Tully Lake. However, as mentioned in the summary, the Commonwealth of Massachusetts has withdrawn support as a sponsor for using Tully Lake as a source of emergency water supply; therefore, this plan is not implementable. Included are descriptions of: present operating regulations, existing water supply conditions, the plan for utilization of short term emergency storage during drought, water quality evaluations, cost for drought storage/releases, impacts on other project purposes, and a conclusion. This report is presented for informational purposes only.

2. AUTHORIZATION

Authority for drought contingency plans is contained in ER 1110-2-1941, dated 15 September 1981, which provides that water control managers continually review and, when appropriate, adjust water control plans in response to changing public needs. Drought contingency plans will be developed on a regional, basin-wide or project basis as an integral part of water control management activities and in accordance with an approved water control plan.

3. PROJECT AUTHORIZATION CONDITIONS

Tully Lake was authorized by the Flood Control Act of 22 June 1936 (Public Law 738, 74th Congress), as amended by Public Law 111 , 75th Congress, approved 28 June 1938.

In May 1964, an approval request for inclusion of a conservation pool for recreational purposes in the flood control reservoir was made to OCE. This request was the result of a combined planning effort of NED and the Massachusetts Department of Natural Resources. Authorization was granted by a letter from OCE, dated 15 July 1964, with the first pool maintained during the summer of 1966.

4. PROJECT DESCRIPTION

Tully Lake, constructed in 1949, is located on the East Branch of the Tully River in Royalston, Massachusetts. Normal elevation of the permanent pool at Tully Lake is 636.0 feet NGVD (11 foot depth) with a total storage volume of about 525 acre-feet. A recreation pool is maintained during the summer months at elevation 641.0 feet NGVD (16-foot depth), with a surface area of 305 acres and total storage of 1500 acre-feet of water (0.60 inch of runoff). An additional 20,525 acre-feet of storage is available above the recreation pool level for flood control purposes up to spillway crest elevation 668.0, equivalent to 7.7 inches of runoff from the 50 square mile drainage area. Area-capacity data for Tully Lake are shown on plate 2.

The outlet works consist of a 6-foot diameter concrete tunnel with an invert elevation at 625.0 feet NGVD. Flow through the outlet is controlled by two 3 feet 6 inches by 5 feet 0 inches electrically operated slide gates.

5. PRESENT OPERATING REGULATIONS

a. Normal Periods. During the nonfreezing season, a 16-foot deep recreation pool is maintained at elevation 641.0 feet NGVD from May to November. During winter, the pool is lowered to an 11-foot depth to elevation 636.0 feet NGVD and maintained from November to May. During periods of normal flow, outflow is maintained equal to inflow by allowing all inflow to pass through the dam.

b. Flood Periods. Tully Lake is operated in concert with other projects in the basin to reduce flooding downstream on the Tully and Millers Rivers and further downstream on the Connecticut River. Operations for floods may be considered in three phases: Phase I - appraisal of storm and river conditions during development of the flood; Phase II - flow regulation and storage of flood runoff at the reservoir; and Phase III - emptying the reservoir following downstream recession of the flood. A minimum release of about 10 cfs is maintained only during periods of flood control regulation in order to sustain downstream fish life. The maximum nondamaging discharge capacity immediately downstream of Tully Lake is about 650 cfs. Releases at or near this rate can be expected whenever peak inflows have exceeded this value and climatologic and hydrologic conditions permit such releases.

c. Monitoring. The Reservoir Control Center directs reservoir regulation activities at 28 manned New England Division flood control dams and monitors rainfall, snow cover, and runoff conditions throughout the region. When any of these hydrologic parameters have been well below normal for several months and possible drought conditions might be developing, the Corps Emergency Operations Center (EOC) will be informed. The EOC will then initiate discussions with the respective Federal and State agencies and in-house Corps elements to review possible drought concerns and future actions.

6. DESCRIPTION OF EXISTING WATER SUPPLY CONDITIONS

a. General. The area of concern is a portion of the north-central region of Massachusetts in the vicinity of Athol and Orange, with parts of this area located in Franklin and Worcester counties. Table 1 contains information about public water suppliers in the area based on information provided by the Massachusetts Department of Environmental Management, Division of Water Resources. Of the eight communities viewed as potential user s of water from Tully Lake during a drought, all or some of the communities are served by a public water supply system. Data are not available for areas dependent on private individual water supplies.

b. Water Supply Systems. The primary objective of this analysis was to accumulate available data regarding water supply systems in the vicinity of Tully Lake that could benefit from storage in the lake and present it in a manner portraying existing water supply conditions. Projections of future demands were not developed because this study only addresses the effects of drought conditions which could occur in the future. Modifications in operational procedures at Tully Lake would provide storage for water supply purposes only when drought conditions exist, and not to meet normal water supply demands at some future date.

c. North-Central Massachusetts Water Suppliers. As noted in table 1, data for each water supplier include: community served, estimated population served by the system, source of supply (ground or surface water), average and maximum day demands for 1980, estimated safe yield of the source, and any additional information available on the source of supply. An analysis of the adequacy of existing sources during drought conditions was not performed. The information has been accumulated to present a summary of the existing water supply conditions for area communities in the vicinity of Tully Lake.

TABLE 1
MAJOR WATER SUPPLIERS - ATHOL-ORANGE AREA

COMPANY OR AGENCY	TOWN SERVED	EST. POPULATION SERVED - 1980	SOURCE OF SUPPLY SW/GW	1980 DEMAND AVG.DAY (MGD)	1980 DEMAND MAX DAY (MGD)	SAFE YIELD (MGD)	COMMENTS
Athol Dept. of Public Works	Athol	10,102	SW/GW	1.16	2.00	1.74	.74 SW - Newton Reservoir, Phillipston Res. 1.00 GW - 1 Well
Millers Falls Fire & Water District	Erving	550			0.04		From Turner's Falls Fire & Water District New well with safe yield of 0.43 MGD expected on line Fall 1983
Gardner Water Dept.	Gardner	17,184	SW	1.92	3.00	1.78	Crystal Lake, Perley Brook, Cowee Pond
Orange Water Dept.	Orange	5,187	GW	0.58	0.93	0.80	Wells New well with safe yield of 0.32 MGD expected on line in 1983
	Phillipston		No Public Water Supply				
South Royalston Improvement Corp.	Royalston	300	GW	0.02	0.06	0.07	1 Well
Templeton Water Dept.	Templeton	5,220	GW	0.49	0.75	1.25	4 Wells
Winchendon Water Dept.	Winchendon	5,855	SW	0.63	0.80	0.70	Upper Naukey Lake

d. Population Projections. Population projections for communities in the vicinity of Tully Lake, presented in table 2, show population trends for each community potentially affected by a prolonged dry period. The projections were provided by the Massachusetts Department of Environmental Management. As can be seen from the table, a decrease in population for the area as a whole is projected for the time period 1980-2000; the general rule being that larger towns will have decreases in population with any growth in population in the smaller communities.

7. SPONSOR

a. General. In an effort to fully implement the Drought Contingency Plans, a local sponsor is required. If a local sponsor cannot be found, then the plan will be considered inactive and drought storage at the Corps Dam will not be studied. The approach is for a State to enter into a contract with the Secretary of the Army (or his representative) and agree to act as wholesaler for all water requirements of individual users. This places local governments in a position to help citizens during difficult times and minimize potential problems that could arise if the Secretary of the Army should determine who is entitled to shares of drought emergency water based on local needs assessments. The sponsor is required to express an interest in utilizing short term storage at the Corps reservoir for emergency water supply. By expressing interest, the sponsor will be required to enter into an emergency water supply contract, specifying the potential water supply available, and costs associated with emergency water releases from the Corps project. This contract will be signed at the time a State-declared drought emergency exists and a request for emergency water supply is received by the Corps.

b. Tully Lake Sponsor. In accordance with letter of August 12, 1991, the Commonwealth of Massachusetts, Department of Environmental Protection (DEP) has identified themselves as the lead Agency to act as sponsor for the Tully Lake Drought Contingency Plan. However, in subsequent letter, dated January 7, 1992, Massachusetts DEP withdrew as a sponsor for drought contingency water supply as local towns in the vicinity of Tully Lake would not clearly benefit from this source of water supply (no surface water treatment facilities exist in this region of Massachusetts).

8. PROPOSED ASSISTANCE PLAN

a. General. There are several authorities that provide use of reservoir storage for water supply at Corps of

TABLE 2
POPULATION PROJECTIONS - ATHOL-ORANGE AREA

TOWN	Actual 1980	1985	1990	1995	2000	PERCENT CHANGE
Athol	10,634	10,359	20,083	9,808	9,532	-10.4
Erving	1,236	1,359	1,392	1,425	1,458	18.0
Gardner	17,900	17,151	16,331	15,511	14,691	-17.9
Hubbardston	1,797	2,013	2,229	2,445	2,661	48.1
Orange	6,844	7,214	7,584	7,954	8,324	21.6
Royalston	955	1,028	1,101	1,174	1,247	30.6
Templeton	6,070	6,147	6,241	6,336	6,430	5.9
Winchendon	7,019	7,124	7,229	7,334	7,439	6.0
	52,455	52,395	52,190	51,987	51,782	-1.3

Engineers projects. They vary from provisions of water supply storage as a major purpose in new projects to discretionary authority to provide emergency supplies to local communities in need. Under authority of ER 1110-2-1941, New England Division is directed to determine short term water supply capability of existing reservoirs that would be functional under existing authorities. Congressional authorization is not required to add municipal and industrial water supply if related revisions in regulation would not significantly affect operation of the project for the originally authorized purposes.

b. Tully Lake Plan

(1) There is no storage allocated for water supply at Tully Lake; therefore, the only existing drought assistance capability would be through increased flexibility of regulation and short term use of project authorized storage. It was determined that the pool can be raised to elevation 642.0 feet NGVD to provide short term drought emergency assistance without compromising the flood control purpose of the project or negatively impacting the recreational aspects of the project. A pool of 642.0 feet NGVD represents a volume of about 325 acre-feet (105 million gallons) over the summer recreation pool or 1,300 acre-feet (423 million gallons) over the winter pool.

(2) The extent of Corps assistance is limited to the time of year drought conditions exist; it is anticipated that there would be enough forewarning to fill the reservoir in the May - June timeframe. By filling to the drought pool in this timeframe the Corps would be in a position to render assistance during the proceeding historic low flow summer months (July - October timeframe). Based on the May through June low flow duration analysis it was determined that during a 10-year frequency drought there would be sufficient riverflow to fill the reservoir from the recreation pool to the drought pool in about a 22-day period. During this period, a minimum release rate from the dam of about 7 cfs (7Q10 for the May-June timeframe) or inflow, whichever is less , would be maintained whenever possible. However, if there is insufficient inflow available or if conditions exist within the watershed that would prevent the Corps from storing water to the drought pool level, the amount of assistance from the Corps may be limited.

(3) Once water is stored at drought pool level and a "declared" drought emergency exists, a water supply contract will be signed by the Corps and the Commonwealth of Massachusetts and emergency releases will be made from the project

upon request from Massachusetts Department of Environmental Protection (DEP). We anticipate that releases will be in addition to passing all inflow through the dam and occur during the July - October timeframe and continue at a magnitude requested by DEP, for emergency water supply until the pool level is lowered to the recreation pool. At that time New England Division will decide whether additional releases could be made to draw down the reservoir to the winter pool.

(4) If assistance is requested outside the May - June timeframe, the time to fill as well as the risk associated with flood protection will have to be decided by New England Division prior to any initiation of drought storage operation. We assume that some variation of the drought procedure mentioned above will be possible to render assistance regardless of the time of year. Minimum release rates (generally equal to the seasonal 7Q10), as well as drought pool filling durations will vary depending on the season of the year assistance is needed. Drought contingency storage versus flow duration at Tully Lake is shown graphically on plate 3.

c. Water Shortage Indicators. The Reservoir Control Center (RCC) will keep abreast of current hydrologic as well as climatologic data at all Corps projects in an effort to aid in recognition of the onset of dry or drought conditions. A series of guide curves have been developed as a tool in this recognition process. Curves such as rainfall-duration-frequency and minimum-surface runoff-frequency were developed for various index stations throughout New England. Selected index stations were based on proximity to Corps reservoirs, period of record, and reliability of data. Guide curves were developed and compared with historic drought data as a way to "track" current observed conditions with comparable historic conditions. Appendix A presents guide curves with an explanation on their development and use. Also presented in appendix A is the Palmer Drought Severity Index (PDSI) classification chart with available New England historic index levels.

As data is monitored by RCC it will be used with these guide curves as well as supplemental information received from various Federal and State Agencies prior to decisions of storing emergency drought water at Tully Lake.

d. Emergency Operations Center. As RCC collects and monitor s climatologic and hydrologic data associated with dry or drought conditions, the Emergency Operations Center (EOC) will be informed. The EOC will initiate discussions with in-house Corps elements as well as with other respective

Federal and State Agencies to review possible drought concerns and future Corps actions. The lead State Agency for Tully Lake is:

Department of Environmental Protection
Water Supply Program
Boston, Massachusetts 02108
Telephone: 617-292-5500

All decisions regarding any Corps action during dry or drought conditions will be made by the EOC.

e. Phases of Drought Assistance. Drought assistance from the Tully Lake project will be given in two phases. Phase I will be during "drought watch" conditions existing within the Tully Lake region of Massachusetts; Phase II - drought emergency is declared by the Commonwealth of Massachusetts. Phases I and II are explained below.

(1) Phase I - Drought Watch. This is the initial phase of implementation of drought assistance. The following conditions and actions will take place during this phase:

(a) Initial indications conclude that a drought condition is developing within this region of Massachusetts. Close coordination between New England Division and other Federal and State agencies, in addition to coordination efforts within New England Division's EOC, have identified that a drought condition is beginning (refer to appendix A for climatologic and hydrologic guide curves of precipitation as well as surface runoff data). This coordination will insure that actions being taken as well as all decisions targeted, to meet specific needs and not react prematurely.

(b) Pending coordination with the Massachusetts Department of Environmental Protection and their subsequent concurrence with the Corps to store water at Tully Lake, subject to the availability of inflow, the Tully project will be filled to elevation 642.0 feet NGVD.

(c) Water will be stored at this level and outflow will be set equal to inflow in order to maintain the pool at a constant level. This pool will be maintained until the Massachusetts DEP formally requests emergency water supply release s during the drought emergency phase. Release rates will be equivalent to inflow plus water supply demand (as requested by DEP).

(2) Phase II - Drought Emergency

(a) A declaration of a drought emergency has been issued by the Massachusetts Department of Environmental Protection.

(b) Department of Environmental Protection contacts New England Division and requests that specific releases be made.

(c) Division Engineer convenes a meeting with Emergency Operations Center to discuss request.

(d) If emergency water supply releases are to be made, a contract between the Commonwealth of Massachusetts and the Corps of Engineers will be signed before any releases are made.

(e) A target release rate, including natural inflow to the dam as well as water release rate requested by DEP, will be determined by NED.

(f) Drawdown of the pool will continue until the pool is lowered to the recreation level. At that time New England Division will decide if continued releases can be made to drawdown the recreation pool to the winter pool level as well as the feasibility of drawing down into the winter pool (during this operation any recovery of water supply storage will be made if conditions permit).

f. Compensation For Use of Storage. As directed by ER 1105-2-100 dated 28 December 1990, compensation must be received for all "emergency drought releases". This compensation will be at least equal to a proper share of annual joint use O&M costs, major replacement expenses, plus revenues foregone as well as any other costs directly attributable to making releases. For Tully Lake, an approximate cost of $ 1,089 has been determined for the release of drought assistance water, based on 1991 dollars. Appendix B presents the Economic Assessment of Drought Contingency Water Supply Pricing at Tully Lake.

9. DISCUSSION OF IMPACTS

a. General. Any action resulting in a temporary change of reservoir storage volume will have impact on authorized project purposes which must be evaluated as part of the drought storage implementation plan. At Tully Lake, the drought contingency plan is one component of the existing approved water control plan. Presented below is a cursory evaluation of the impacts on the flood control and recreation purposes of the project, resulting from drought contingency storage. Effects on environmental as well as historic and archaeological resources will be addressed at a time when an updated Environmental Assessment (EA) for operation of the project has been completed.

b. Flood Control. A review of regulation procedures at Tully Lake was undertaken to determine the volume of water that could be made available for emergency drought contingency purposes. The water would be stored by temporarily utilizing existing flood control storage. Major floods occur in every season of the year and any use of flood control storage would be continually monitored to insure there would be no adverse impacts on downstream flood protection.

At Tully Lake, the maximum pool elevation for drought contingency storage has been estimated to be elevation 642.0 feet NGVD, representing an infringement on flood control storage of about 0.1 inch, from total storage capacity of 7.7 inches of runoff from the upstream 50 square mile drainage area. At elevation 642.0 feet NGVD, water could be stored without significantly affecting flood control capability or other regulation activities.

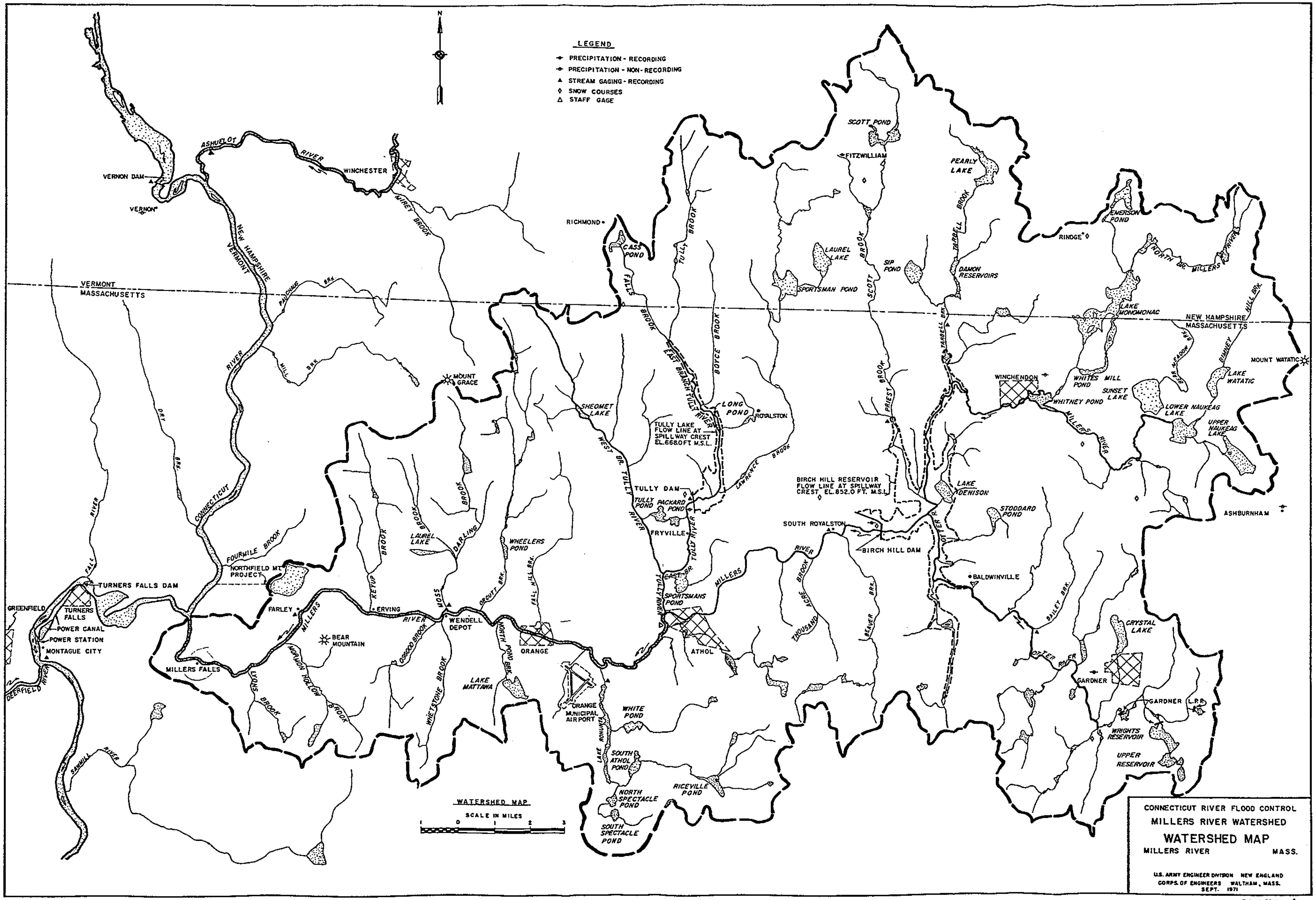
c. Recreation. No adverse impacts as recreational features at Tully Lake will be unaffected by the proposed 1-foot increase in pool level for drought contingency purposes.

d. Water Quality. Drought contingency storage at Tully Lake would raise the pool 1.0 foot above its recreation pool elevation of 641.0 to an elevation of 642.0 feet NGVD, an increase in depth from 16 to 17 feet. This increase would occur only during a drought period. Water quality effects that could result from increased storage include reduced dissolved oxygen levels, increases in water temperature, iron, manganese, ammonia, phosphorus, color, and suspended solids. These increases would be minor and are not expected to threaten aquatic life or human heath . Although the lake would be subject to a greater potential for occurrence of localized algae blooms, severe algae problems are not anticipated and trophic status of the lake should remain unchanged. Effects of drought storage operations on downstream water quality are expected to be minimal as well. Water quality degradation would occur during droughts, regardless of increased storage, as lake water tends to stagnate and most water quality conditions worsen during extended periods of low flow. The waters of Tully Lake would require standard treatment processes for drinking water supply, but no treatment would be necessary for fire fighting, irrigation, and most industrial uses in the event of drought storage implementation. Appendix C presents a comprehensive water quality evaluation regarding drought contingency storage at Tully Lake.

10. CONCLUSIONS

A drought contingency plan was developed for Tully Lake that would be responsive to public needs during drought situations. The plan would permit encroachment on flood control storage to elevation 642 feet NGVD, providing an emergency water supply contingency of about 325 acre-feet (105 million gallons) over the summer recreational pool, or in times of extreme emergency, a potential 1,300 acre-feet (423 million gallons) over the winter pool. An evaluation of the effects of this drought contingency plan on various project features as well as water quality has revealed no significant impacts. The Commonwealth of Massachusetts has withdrawn support as a sponsor for implementing this plan. As local towns within the Tully Lake vicinity rely on groundwater sources for water supply, there is no interest in using surface water from Tully Lake.

<u>THIS PLAN IS THEREFORE NOT IMPLEMENTABLE</u>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MILL BRK.
DRY BRK.
BAILEY BRK.
BINNEY HILL BRK.
NORTH BR. MILLERS RIVER
LAKE ROHUNTA

PLATE /

TULLY RESERVOIR
AREA AND CAPACITY

DRAINAGE AREA = 50 SQ. MI.

ELEV. FT-NGVD	STAGE FEET	AREA ACRES	CAPACITY AC. FT.	CAPACITY INCHES
625	0	0	0	0
626	1	5	5	0
627	2	10	10	0
628	3	17	15	.01
629	4	20	20	.01
630	5	23	25	.01
631	6	32	125	.05
632	7	38	200	.08
633	8	45	225	.08
634	9	55	375	.14
635	10	65	425	.16
	Permanent Pool = 636			
636	11	78	525	.20
637	12	95	650	.24
638	13	112	825	.31
639	14	140	1,025	.39
640	15	210	1,225	.46
641	16	305	1,500	.60
	Recreation Pool = 641			
641	16	305	0	0
642	17	365	325	.12
643	18	420	700	.26
644	19	465	1,100	.41
645	20	505	1,525	.57
646	21	545	1,975	.74
647	22	580	2,525	.95

ELEV. FT-NGVD	STAGE FEET	AREA ACRES	CAPACITY AC. FT.	CAPACITY INCHES
648	23	615	3,075	1.16
649	24	650	3,625	1.36
650	25	685	4,225	1.59
651	26	710	4,875	1.83
652	27	745	5,550	2.09
653	28	775	6,325	2.38
654	29	800	7,125	2.68
655	30	825	7,950	2.99
656	31	855	8,775	3.30
657	32	880	9,600	3.61
658	33	905	10,450	3.93
659	34	930	11,300	4.25
660	35	955	12,250	4.61
661	36	980	13,225	4.97
662	37	1,005	14,150	5.32
663	38	1,025	15,225	5.78
664	39	1,050	16,225	6.10
665	40	1,075	17,250	6.49
666	41	1,095	18,425	6.93
667	42	1,115	19,525	7.34
668	43	1,140	20,525	7.72
	Crest Elevation = 668			
669	44	1,160	21,525	8.09
670	45	1,185	22,525	8.47
671	46	1,205	23,525	8.85
672	47	1,225	24,525	9.22
673	48	1,245	25,525	9.60

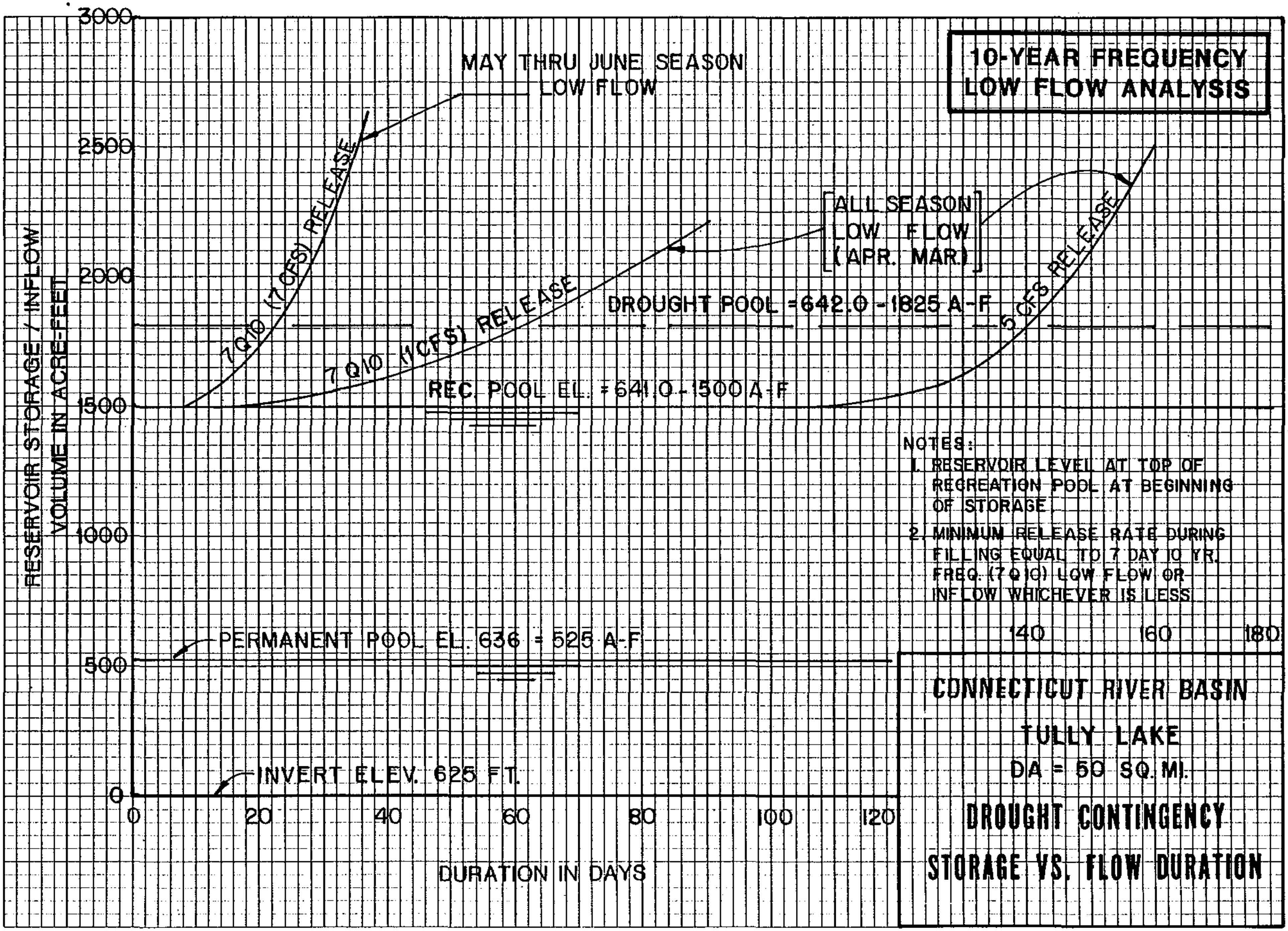
10-YEAR FREQUENCY
LOW FLOW ANALYSIS
MAY THRU JUNE SEASON
LOW FLOW
7Q10 (7 CFS) RELEASE
7 Q10 (1CFS) RELEASE
ALL SEASON
LOW FLOW
(APR. MAR.)
5 CFS RELEASE
DROUGHT POOL = 642.0 - 1825 A-F
REC. POOL EL. = 641.0 - 1500 A-F
PERMANENT POOL EL. 636 = 525 A-F
INVERT ELEV. 625 FT.
RESERVOIR STORAGE / INFLOW
VOLUME IN ACRE-FEET
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
180
DURATION IN DAYS
NOTES:
1. RESERVOIR LEVEL AT TOP OF RECREATION POOL AT BEGINNING OF STORAGE.
2. MINIMUM RELEASE RATE DURING FILLING EQUAL TO 7 DAY 10 YR. FREQ. (7 Q 10) LOW FLOW OR INFLOW WHICHEVER IS LESS.
CONNECTICUT RIVER BASIN
TULLY LAKE
DA = 50 SQ. MI.
DROUGHT CONTINGENCY
STORAGE VS. FLOW DURATION

PLATE 3

APPENDIX A

CLIMATOLOGIC AND HYDROLOGIC INDICATORS

APPENDIX A

DROUGHT CONTINGENCY PLAN
CLIMATOLOGIC AND HYDROLOGIC INDICATORS

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LIST OF TABLES

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DROUGHT CONTINGENCY PLAN
CLIMATOLOGIC AND HYDROLOGIC INDICATORS

1. INTRODUCTION

This appendix is presented to supplement the developed Drought Contingency Plan with climatological as well as hydrological data that are useful towards identifying and recognizing periods of dry or drought conditions. The analyses presented is not intended to predict a drought, as most drought predicting measures are not considered very accurate or promising. It is however, intended to aid in recognizing the onset of water shortage conditions in an effort to mitigate their impacts prior to severe or emergency conditions prevailing. It is most beneficial to recognize the beginning of a drought rather than to initiate action <u>after</u> the drought's effect become apparent.

The data presented is in the form of "guide curves" and do not serve the purpose of a single "trigger" in which emergency drought storage at Corps reservoirs would be initiated. As stated in the main text of the Drought Contingency Plan, NED's decision to store emergency water supply would be based on a combination of the guide curves as well as information received from various Federal and State agencies.

The data presented is an attempt to show regional indicators of dry or drought periods. While specific index stations were used in developing the guide curves, their use is not to be restricted to that station only. Their application is considered to represent generalized conditions in areas within the region.

Indicators such as rainfall-duration-frequency and minimum surface runoff-duration frequency were developed for various index stations within New England. Index stations selected were based on proximity to Corps drought contingency candidate reservoirs, period of record and reliability of data. The guide curves were developed and compared with historic drought data as a way to "track" current observed conditions with comparable historic conditions. Also presented is the Palmer Drought Severity Index (PDSI) classification chart with available New England historic drought index levels indicated.

2. DROUGHTS

a. <u>General.</u> Hydrologically, drought is defined as a prolonged period of precipitation deficiency which seriously affects riverflow as well as surface and groundwater supplies. The duration, magnitude, severity, frequency and areal extent have been identified as five common characteristics of drought. These characteristics are applicable to drought whether measured by precipitation, streamflow, reservoir levels or by the Palmer index.

b. History. Drought history in New England before 1900 is rather limited. Periods of precipitation deficiencies were experienced, however, records of runoff deficiency are relatively non-existent. Since the establishment of streamflow gaging stations, low flow periods and drought conditions have been observed throughout the New England river basins at various times. Serious droughts occurred within New England during the periods 1924-1927; 1929-1933 and 1961-1967.

c. Drought of Record. The drought of 1961 to 1967 was the longest and most severe in the history of the New England region. This was the severest in nearly 170 years of precipitation records in Boston, Massachusetts. The 1960's drought followed a period of above normal precipitation which contributed to relaxation on the part of cities and towns during what was really a period of rapidly increasing water demand. In addition, a considerable number of water facilities failed since most had been designed to meet a repetition of the less severe drought of the 1930's.

During the period 1963 through 1966, the cumulative precipitation deficiencies (i.e. total amount below normal) varied from about 40 to 60 inches throughout New England, which is equivalent to 1 to 1.3 years of normal rainfall.

The accumulative deficiency in the average runoff for water years 1962 to 1966 varied from about 25 to 50 inches throughout New England, equivalent to about 1 to 2 years of average annual runoff.

3. CLIMATOLOGIC AND HYDROLOGIC ANALYSIS

a. General. Streamflow, reservoir levels, ground water levels, soil moisture, precipitation and the Palmer Drought Severity Index are some of the indicators used by drought managers for early detection as well as continued tracking of a drought. This analysis focused on three of these indicators: rainfall; runoff and the Palmer Index. Rainfall and runoff were selected due to the large magnitude of available historic as well as current data. The Palmer Index was selected primarily due to its wide acceptance as a reliable drought indicator. While many more parameters are used in the drought identification process, it is believed that for purposes of the Drought Contingency Plans the parameters selected and the analysis performed offer a reasonable approach to drought management at NED reservoirs.

b. Climatological Data. Rainfall frequencies for 1, 3, 6 and 12 month durations were developed for various index stations. The curves were developed using the period of record monthly rainfall data at each index station. Accumulative tabulations were made for 1, 3, 6 and 12 consecutive months, assigning Weibull plotting positions and fitting the curves through the data. Index stations selected, with their corresponding periods of record, as well as the mean, maximum and minimum monthly rainfall, are shown in tables 1 through 3. The computed frequency curves are graphically shown on plates 1 through 3. Historic data, where available, was plotted on the 3, 6 and 12 month duration curves. The historic data was presented to allow comparison with any current data to that which occurred during historic droughts. This comparative analysis allows for a better understanding of the drought or dry period being experienced and provides for a historical perspective during drought tracking procedures.

Although the 1 and 3 month durations are presented, it is suggested that any drought emergency actions or conclusions not be based solely on the data of these short durations. In the New England region, experience has shown that low rainfall amounts for durations of 1 and 3 months do not necessarily constitute a dry or drought condition. For example: During the winter of 1988/1989 rainfall was historically low for a consecutive 3 month duration, measuring 6.5 inches at Storrs, Ct. Applying this rainfall to the 3 month curve identified the frequency to be about a 16 year drought, tracking somewhere between the historic droughts of 1924-1927 and 1980-1981. However, when the 6 month cumulative rainfall, during the same dry period, computed to be 21.5 inches, was applied to the 6 month curve, the frequency became less critical, equivalent to about a 2 year event. On an annual duration, the total 1989 rainfall amounts were considered at or above normal despite record low 3 month durations. Had drought emergency measures been implemented solely on the 3 month duration data it would have been proven to be premature or unnecessary. It is therefore recommended that although 1 and 3 month rainfall amounts should not be ignored, durations greater than 3 months should always be considered prior to any emergency drought plans being implemented.

c. Hydrologic Data. Streamflow data measured and published by the U.S. Geological Survey was used exclusively in all hydrologic analysis performed as part of this appendix. Since this analysis concerned itself with low streamflows, an attempt was made to identify and use streamflow index stations that are not regulated during periods of low flow. While many New England rivers and streams are regulated, to some extent, by mill pond dams, as well as other run of river type dams, it was assumed that any occasional regulation of low flows on the index stations selected would be considered to be minor and have minimal affect on natural low flow conditions. The mean, maximum and minimum monthly flows for four USGS gaging stations used as index stations in this report are presented in tables 4 through 7.

An annual low flow frequency analysis was made of the historical low flow data for each selected USGS gaging station. Low flows were determined for durations of 1, 3, 14, 30, 60, 90, 183 and 365 consecutive days for each climatological year (1 April

TABLE A-1

PRECIPITATION SUMMARY (INCHES)
STORRS, CONNECTICUT
ELEVATION 650 FT. NGVD
(101 Years of Record)

Month	Mean	Maximum	Minimum
January	3.65	13.79	0.64
February	3.25	7.89	0.37
March	3.94	10.65	0.15
April	3.80	10.94	0.55
May	3.76	9.21	0.33
June	3.33	12.79	0.29
July	4.15	12.15	0.78
August	4.19	14.75	0.47
September	3.84	17.00	0.45
October	3.64	8.82	0.15
November	4.00	9.24	0.47
December	3.84	9.97	0.68
ANNUAL	44.90	66.31	29.16

TABLE A-2

PRECIPITATION SUMMARY (INCHES)
AMHERST, MASSACHUSETTS
ELEVATION 150 FT. NGVD
(64 Years of Record)

Month	Mean	Maximum	Minimum
January	3.11	8.16	0.49
February	2.81	7.58	0.08
March	3.44	8.24	0.24
April	3.61	8.99	0.55
May	3.75	11.95	0.83
June	3.97	10.25	0.72
July	3.74	10.56	0.00
August	3.73	16.10	0.67
September	3.77	14.55	0.94
October	3.17	8.10	0.32
November	3.84	8.65	0.70
December	3.47	8.77	0.58
ANNUAL	42.55	60.25	29.55

TABLE A-3

PRECIPITATION SUMMARY (INCHES)
CONCORD, NEW HAMPSHIRE
ELEVATION 350 FT. NGVD
(69 Years of Record)

Month	Mean	Maximum	Minimum
January	2.69	8.09	0.40
February	2.45	7.77	0.03
March	3.12	10.36	0.55
April	3.11	6.63	0.42
May	3.10	9.52	0.60
June	3.34	10.10	0.64
July	3.38	7.57	0.96
August	3.01	6.88	0.95
September	3.16	10.68	0.41
October	2.85	8.78	0.05
November	3.73	7.59	0.50
December	4.56	10.34	0.58
ANNUAL	38.26	54.29	24.17

TABLE A-4

MONTHLY STREAM FLOW
QUINEBAUG RIVER AT JEWETT CITY, CT
DRAINAGE AREA = 713 Sq. Miles
(1919 - 1990)

Month	Mean		Maximum		Minimum	
	cfs	inches	cfs	inches	cfs	inches
January	1566	2.52	5694	9.18	219	0.35
February	1664	2.19	3919	5.16	473	0.62
March	2530	4.08	6930	11.17	1220	1.97
April	2436	3.68	5519	8.33	854	1.29
May	1534	2.47	2842	4.58	620	1.00
June	1033	1.56	4758	7.18	262	0.40
July	578	0.93	4110	6.63	138	0.22
August	498	0.80	3918	6.32	98	0.16
September	532	0.80	3502	5.28	97	0.15
October	630	1.02	3279	5.29	132	0.21
November	1066	1.61	3443	5.19	189	0.29
December	1434	2.31	4125	6.65	281	0.45
ANNUAL	1293	23.54	2015	38.24	598	11.35

TABLE A-5

MONTHLY STREAM FLOW
WEST BRANCH WESTFIELD RIVER
AT HUNTINGTON, MA
DRAINAGE AREA = 94 Sq. Miles
(1935 - 1990)

Month	Mean		Maximum		Minimum	
	cfs	inches	cfs	inches	cfs	inches
January	173	2.12	448	5.49	24	0.29
February	185	2.05	712	7.88	35	0.39
March	369	4.52	1098	13.46	112	1.37
April	503	5.97	1069	12.68	116	1.38
May	257	3.15	761	9.33	76	0.93
June	141	1.67	684	8.11	27	0.32
July	66	0.81	307	3.76	10	0.12
August	57	0.69	632	7.75	9	0.11
September	64	0.76	579	6.87	9	0.11
October	102	1.25	1041	12.76	13	0.16
November	173	2.05	544	6.45	25	0.30
December	195	2.39	664	8.14	40	0.49
ANNUAL	190	27.36	296	42.62	74	10.66

TABLE A-6

MONTHLY STREAM FLOW
SMITH RIVER NEAR BRISTOL, NH
DRAINAGE AREA = 86 Sq. Miles
(1918 - 1990)

Month	Mean		Maximum		Minimum	
	cfs	inches	cfs	inches	cfs	inches
January	99	1.33	253	3.39	19	0.25
February	99	1.20	578	7.00	21	0.25
March	254	3.41	1242	16.65	30	0.40
April	487	6.33	1077	14.00	183	2.38
May	230	3.08	504	6.76	72	0.97
June	104	1.35	353	4.59	21	0.27
July	52	0.70	387	5.19	9	0.12
August	34	0.46	168	2.25	5	0.07
September	41	0.53	457	5.94	8	0.10
October	68	0.91	267	3.58	9	0.12
November	127	1.65	379	4.93	25	0.33
December	131	1.76	393	5.27	22	0.29
ANNUAL	143	22.57	223	35.19	65	10.26

TABLE A-7

MONTHLY STREAM FLOW
WEST RIVER AT NEWFANE, VT
DRAINAGE AREA = 308 Sq. Miles
(1919 - 1990)

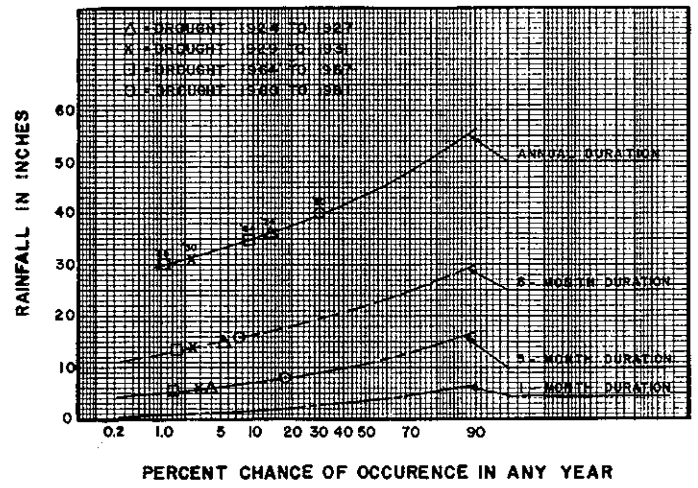
Month	Mean		Maximum		Minimum	
	cfs	inches	cfs	inches	cfs	inches
January	452	1.69	1515	5.67	95	0.36
February	444	1.50	1497	5.06	109	0.37
March	1090	4.08	3712	13.89	184	0.69
April	2199	7.92	4411	15.88	589	2.12
May	1010	3.78	2733	10.23	249	0.93
June	403	1.45	1439	5.18	64	0.23
July	205	0.77	1321	4.94	29	0.11
August	159	0.60	1539	5.76	36	0.13
September	200	0.72	1667	6.00	22	0.08
October	337	1.26	1768	6.61	33	0.12
November	567	2.04	1437	5.17	91	0.33
December	556	2.08	1578	5.91	137	0.51
ANNUAL	636	28.02	1084	47.77	272	11.98

to 31 March) using the USGS "WATSTORE" data storage and retrieval computer system. The annual low flows for each duration were fitted to a Log Pearson Type III distribution. The fitting technique involves transforming annual low flow values to logarithmic values and finding the mean, standard deviation and skew coefficient of the logarithms. The computed low flow frequency duration curves are shown graphically on plates 1 through 3. Historical data, where available, was plotted for each index station. It is noted that low flow duration curves are not shown less than a 30 day period. Within New England, low streamflow data, over a consecutive period of less than 30 days, is considered to be inconclusive when assessing drought conditions.

d. <u>Palmer Drought Severity Index (PDSI).</u> The Palmer Drought Severity Index is a widely used indicator of drought conditions. It is published in the following: "Weekly Weather and Crop Bulletin" prepared jointly by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Agriculture (USDA); "Weekly Climate Bulletin" of the NOAA, Climate Analysis Center; and monthly "National Water Conditions" report of the U.S. Geological Survey. The National Climate Center computes the PDSI for all climate divisions in the contiguous United States.

The PDSI is a meteorological index that reflects estimates of departure of soil moisture from normal. Normal moisture conditions are derived from period of record data including monthly averages of evapotranspiration, soil water recharge, runoff and water loss from the soil. The index is standardized so that it has a consistent meaning in different climate areas and from month to month. The classification system translates the numerical value of the index to a descriptive measure of drought or wetness. The dry periods on the index are classified as extreme drought and assigned a numerical value of -4.0. The region on the PDSI graph between extreme drought and near normal conditions was subdivided into three additional drought categories: Severe (PDSI = -3.0): Moderate (PDSI = -2.0); and Mild (PDSI = -1.0). The current PDSI classification system is shown graphically on plates 1 through 3. Also shown on the PDSI graphs are the classifications assigned by others to some historic droughts data that occurred throughout New England.

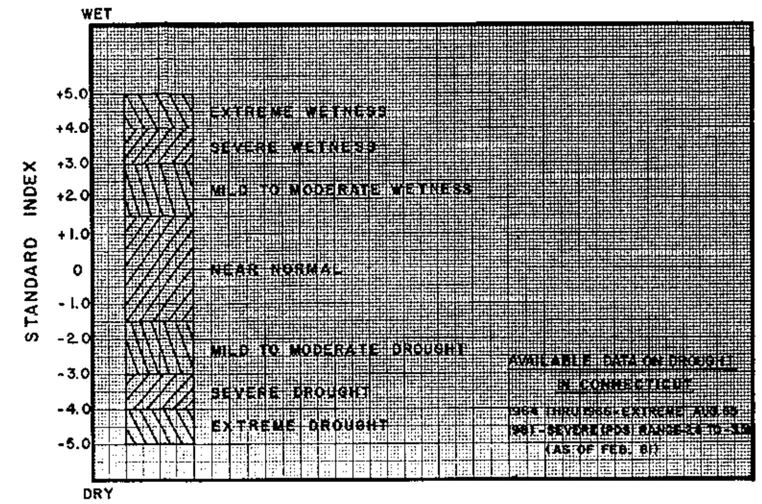
The PDSI is presented as a tool in assessing current wet or dry conditions only and should be used in conjunction with other hydrological and climatological data for effective drought management. The PDSI should not be used for drought planning or hydrologic drought forecasting.



RAINFALL DURATION CURVES

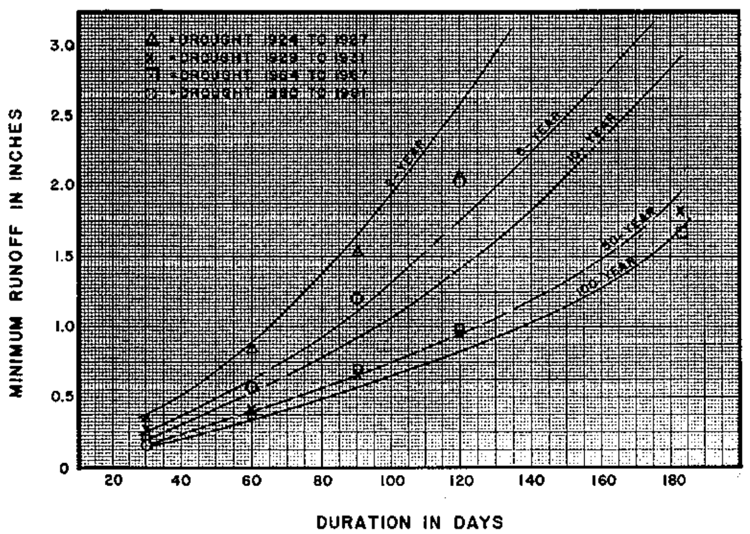
STORRS, CONNECTICUT (EL.= 650.0 FT. N.G.V.D.)

PERIOD OF RECORD 101 YRS.



PALMER DROUGHT SEVERITY INDEX (PDSI)

STANDARD CLASSIFICATION INDEX OF WET AND DRY PERIODS

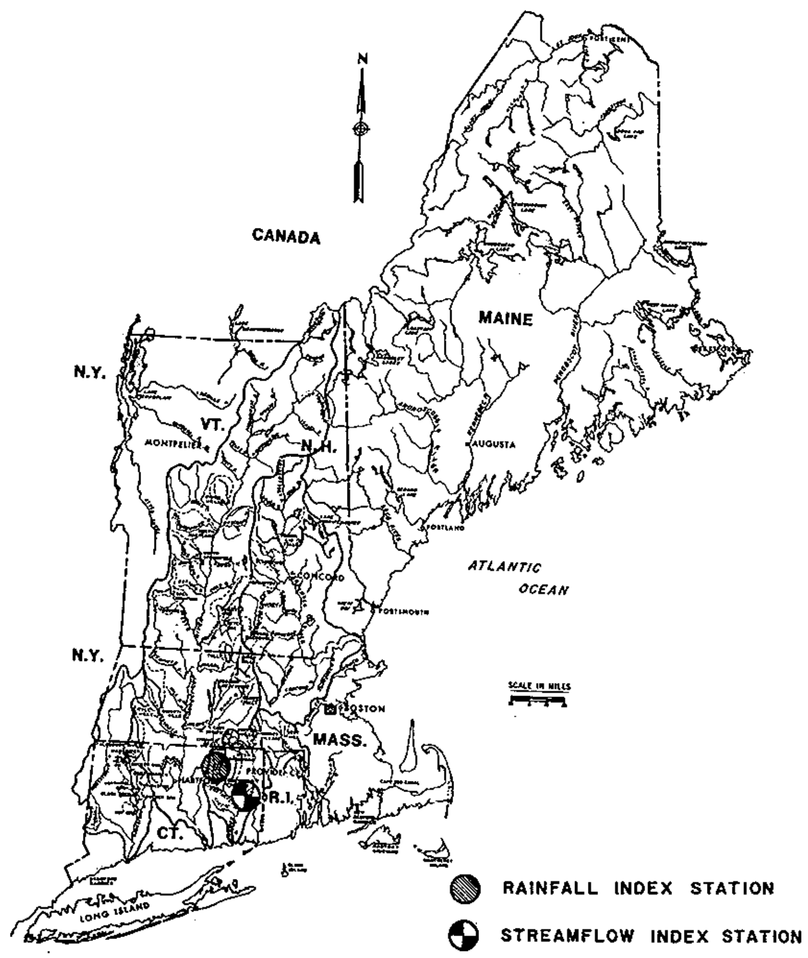


MINIMUM RUNOFF-FREQUENCY CURVES

QUINEBAUG RIVER AT JEWETT CITY, CONNECTICUT

D.A. = 713 SQ. MI.

PERIOD OF RECORD 73 YRS.



RAINFALL AND STREAMFLOW LOCATION MAP

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

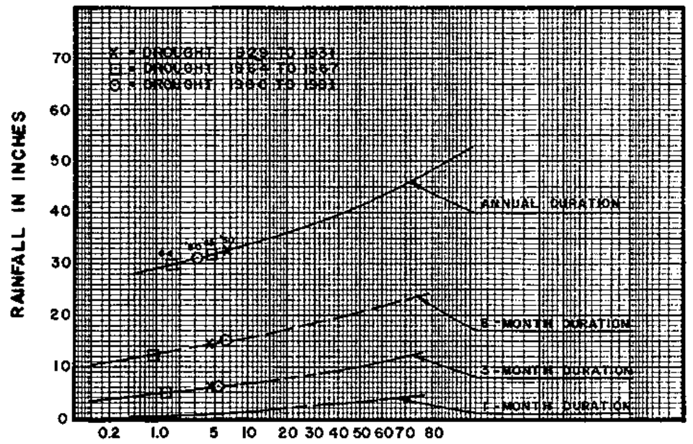
DROUGHT CONTINGENCY PLAN

RAINFALL AND RUNOFF

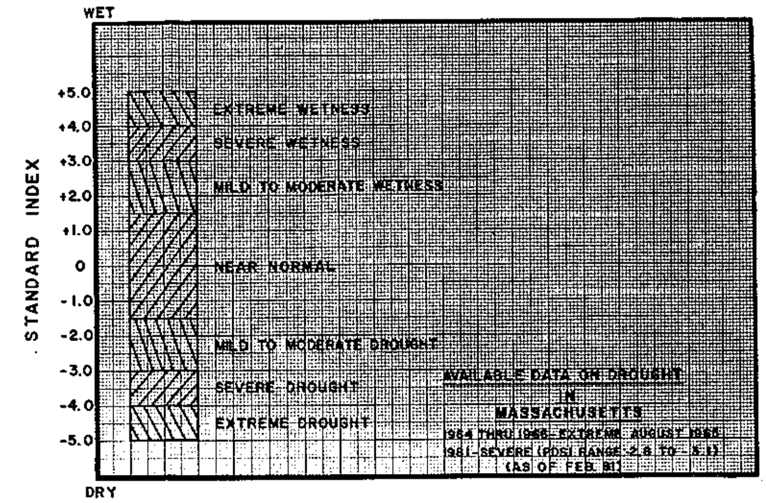
GUIDE CURVES FOR

SOUTHERN NEW ENGLAND

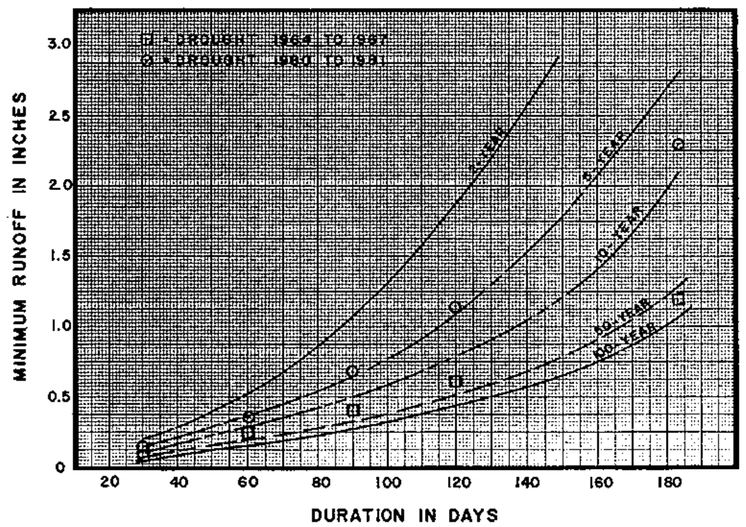
PLATE A1



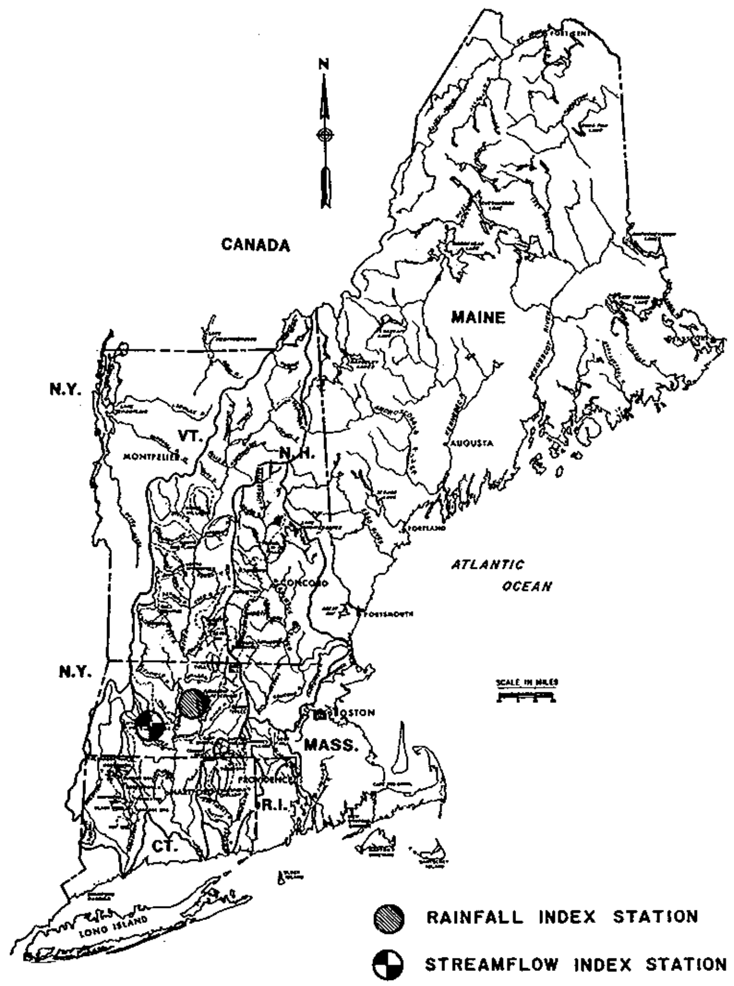
RAINFALL DURATION CURVES
AMHERST, MASSACHUSETTS (EL.= 150.0 FT. N.G.V.D.)
PERIOD OF RECORD 64 YRS.



PALMER DROUGHT SEVERITY INDEX (PDSI)
STANDARD CLASSIFICATION INDEX OF WET AND DRY PERIODS



MINIMUM RUNOFF-FREQUENCY CURVES
WEST BRANCH WESTFIELD RIVER AT
HUNTINGTON, MASSACHUSETTS
D.A. = 94 SQ. MI.
PERIOD OF RECORD 54 YRS.



RAINFALL AND STREAMFLOW LOCATION MAP

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

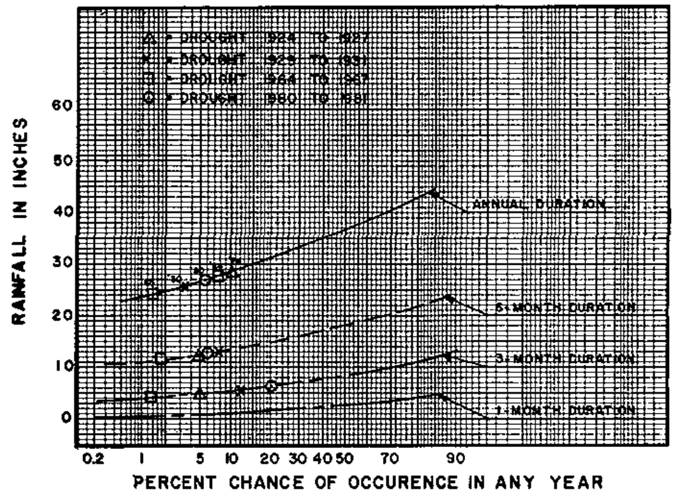
DROUGHT CONTINGENCY PLAN

RAINFALL AND RUNOFF

GUIDE CURVES FOR

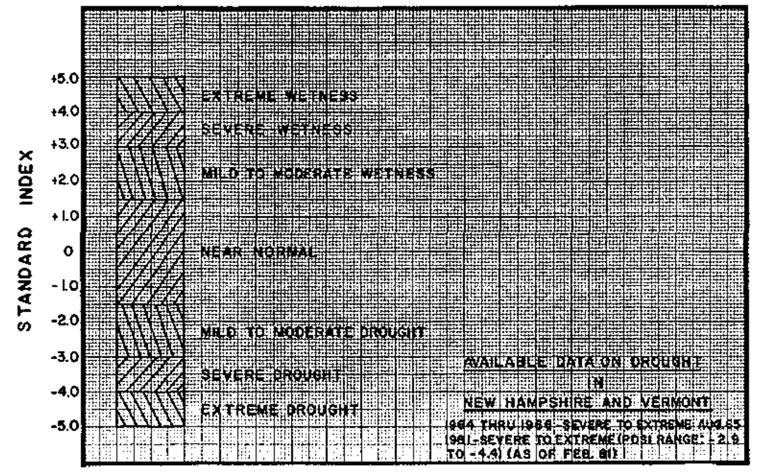
MASSACHUSETTS AND SOUTHERN N.H.

PLATE A2



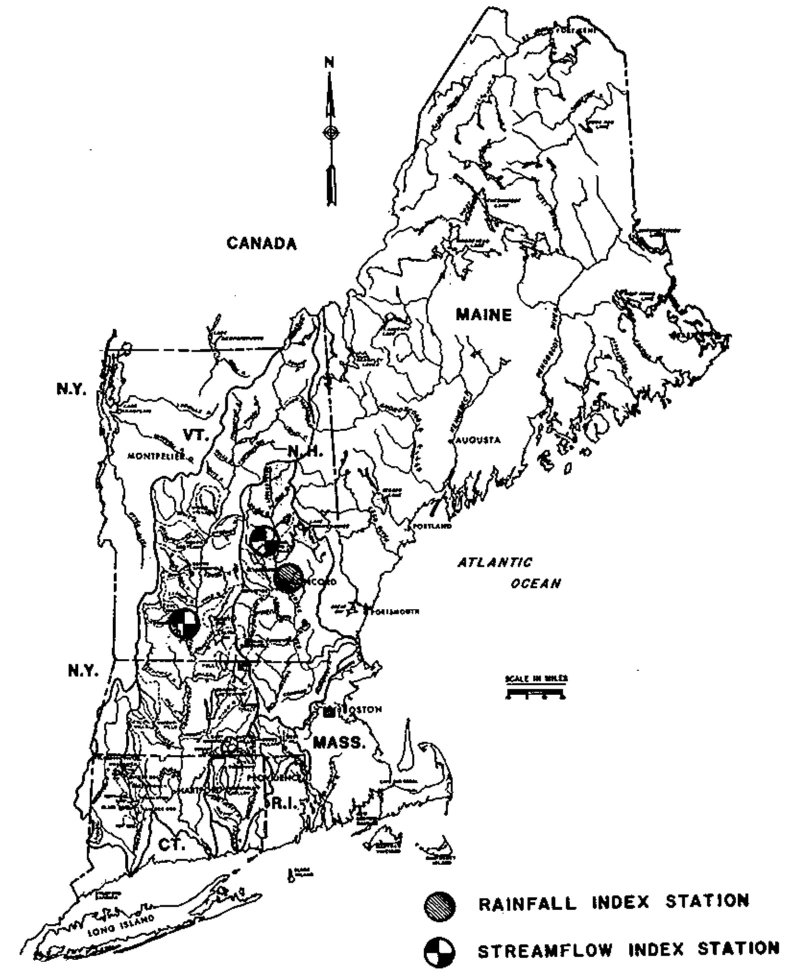
RAINFALL DURATION CURVES

CONCORD, NEW HAMPSHIRE (EL. = 350.0 FT. N.G.V.D.)
PERIOD OF RECORD 69 YRS.

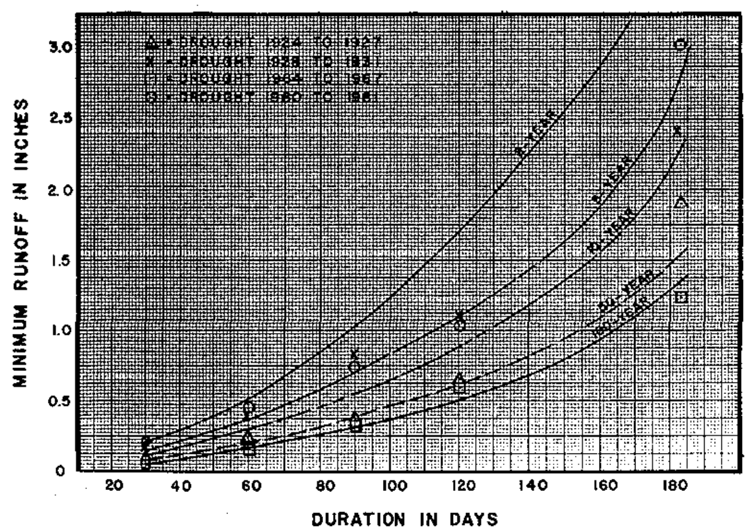


PALMER DROUGHT SEVERITY INDEX (PDSI)

STANDARD CLASSIFICATION INDEX OF WET AND DRY PERIODS

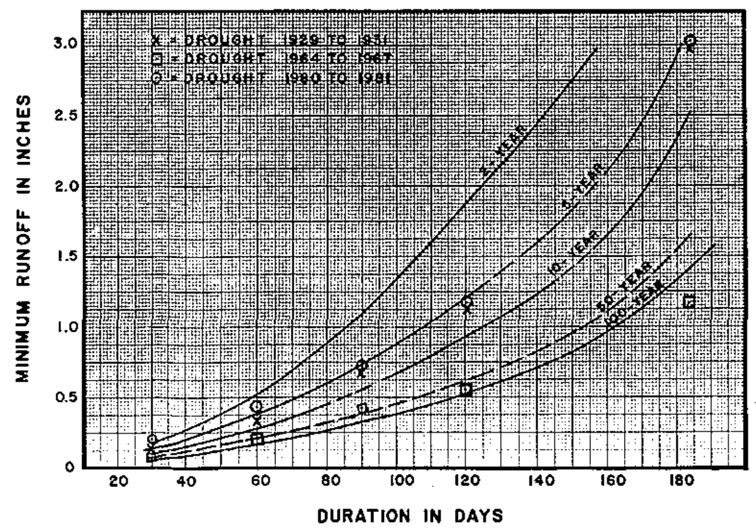


RAINFALL AND STREAMFLOW LOCATION MAP



MINIMUM RUNOFF-FREQUENCY CURVES

SMITH RIVER NEAR BRISTOL NEW HAMPSHIRE
D.A. = 85.8 SQ. MI.
PERIOD OF RECORD 71 YRS.



MINIMUM RUNOFF FREQUENCY CURVES

WEST RIVER AT NEWFANE, VERMONT
D.A. = 308 SQ. MI.
PERIOD OF RECORD 63 YRS.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DROUGHT CONTINGENCY PLAN

RAINFALL AND RUNOFF

GUIDE CURVES FOR

NEW HAMPSHIRE AND VERMONT

APPENDIX B

ECONOMIC ASSESSMENT

ECONOMIC ASSESSMENT OF
DROUGHT CONTINGENCY WATER SUPPLY PRICING
at TULLY LAKE RESERVOIRS

APPENDIX B

PREPARED BY:
ECONOMIC AND RESOURCE ANALYSIS BRANCH
IMPACT ANALYSIS DIVISION
PLANNING DIRECTORATE

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
NEW ENGLAND DIVISION

JULY 1991

ECONOMIC ASSESSMENT OF
DROUGHT CONTINGENCY WATER SUPPLY PRICING
at TULLY LAKE RESERVOIR

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INTRODUCTION

The purpose of this report is to develop a methodology to be used to develop a price for drought contingency water supply. The methodology is developed in accordance with ER 1105-2-100, Chapter 4, Section 7 with the exception of including updated construction cost as an element of the price to be charged to the non-federal user.

METHODOLOGY

The amount to be charged for drought contingency water is determined by finding the appropriate share of joint cost attributed to drought contingency water supply, obtaining all cost that can be attributed to the provision of drought contingency water, and accounting for any benefits forgone from the existing project due to the provision of drought contingency water.

The joint cost of providing water is determined by deducting specific cost from total operation, maintenance, replacement and major rehabilitation. The non-federal share of joint cost applied to drought contingency is determined by dividing the volume in acre-feet devoted to drought contingency water supply by the total usable storage space in acre-feet. This ratio is then multiplied by annual joint use cost to determine the non-federal share.

To the joint use annual cost is added any separable cost that is due entirely to the drought contingency water supply function. Reductions in project benefits are then calculated (if any) and added to the non-federal share.

The price will be determined on an annual basis and updated for each year of the drought contingency water supply contract with the non-federal user.

WATER SUPPLY PRICE

The development of a price to be charged the non-federal user is shown in Table 1.

Joint Use Cost

Joint Use Cost is project cost that cannot be separated by type of project benefit. This cost is obtained by deducting from total O & M cost (Column 3) that is specific to recreation (Column 4). The result is shown in Column 5. The share that is attributed to water supply is obtained by dividing acre-feet available for drought contingency water supply (Column 1) by total acre-feet of available storage (Column 2). This factor is then multiplied by joint use O&M (Column 5) and Rehabilitation and Replacement (Column 6) to determine that portion of joint cost that is to be allocated to drought contingency water supply. The result is shown in columns 9 and 10.

Table 1
Drought Contingency
Water Supply Pricing
1991 Price Level

RESERVOIR	WS-VOL (AC-FT)	TOT-VOL (AC-FT)	TOT O&M (000)	REC O&M (000)	JT O&M (000)	JT REHAB (000)	SEP WS (000)	LOST REC (000)	JT O&M-WS (000)	REHAB-WS (000)	WS-ANN'L	WS-DAILY
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
TULLY LAKE	325	20,525	381.1	31.7	349.4	100	0	0	5.5	1.6	$1089.	$19.45

Benefits Foregone

Recreation benefit at Tully Lake would not be affected by the water supply function. The recreation features of Tully Lake include boating. The provision of a drought contingency pool does not affect recreation activities at Tully Lake.

SUMMARY

The daily price to be charged for drought contingency water supply (Table 1, Column 12) is obtained by adding water supply's share of joint O&M and major rehabilitation and replacement cost (Cols. 9 and 10) and dividing by 365. To this is added separable water supply cost and foregone recreation value. These latter two magnitudes are put on a daily basis by dividing by 56 days which is the period that drought contingency water supply would be available. Annual cost shown in Col. 11 is obtained by multiplying col. 12 by 56.

Drought contingency water supply price should be established for a period of one year and updated in successive years based upon changes in O&M, major rehabilitation and replacement and recreation value.

APPENDIX C

WATER QUALITY EVALUATION

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WATER QUALITY EVALUATION
TULLY LAKE DROUGHT CONTINGENCY STUDY
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APPENDIX C

WATER QUALITY EVALUATION
TULLY LAKE DROUGHT CONTINGENCY STUDY
ROYALSTON, MASSACHUSETTS

1. SUMMARY

Drought contingency storage at Tully Lake would raise the pool 1.0 foot above its current elevation of 641.0 to 642.0 feet NGVD, and from a maximum depth of 16 to 17 feet. This increase would only occur during a declared drought period. Water quality effects that could result from increased storage include reduced dissolved oxygen levels, and increases in water temperature, iron, manganese, ammonia, phosphorus, color, and suspended solids. These increases would be minor and are not expected to threaten aquatic life or human health. Although the lake would be subject to a greater potential for the occurrence of localized algae blooms, severe algae problems are not anticipated and trophic status of the lake should remain unchanged. Effects of drought storage operations on downstream water quality are expected to be minimal as well. Water quality degradation would occur during droughts, regardless of increased storage, as lake water tends to stagnate and most water quality conditions worsen during extended periods of low flow. The waters of Tully Lake would require standard treatment processes for drinking water supply, but no treatment would be necessary for fire-fighting, irrigation, and most industrial uses in the event of drought storage implementation.

2. WATER QUALITY CLASSIFICATION

The entire length of the East Branch Tully River and its tributaries in Massachusetts are rated class B by the Massachusetts Division of Water Pollution Control (MDWPC). According to the MDWPC, class B waters are designated acceptable as a habitat for aquatic life and wildlife, and for primary and secondary contact recreation. These waters are also suitable for public water supply following appropriate treatment, irrigation and other agricultural uses, and compatible industrial cooling and process uses.

Technical requirements for class B waters include a minimum dissolved oxygen concentration of 5 mg/l, pH in the range of 6.5 to 8.3 standard units, no fecal coliform bacteria in excess of a log mean of 200 organisms per 100 ml sample, and maximum water temperature of 83 degrees

Fahrenheit. These standards further prohibit color, turbidity, solids, taste and odor that are aesthetically objectionable or would impair any use assigned to this class; and also require that the waters shall be free from pollutants in concentrations that exceed the most sensitive receiving water use.

3. EXISTING WATER QUALITY CONDITIONS

a. General. Relatively few sources of pollution contribute to the Tully Lake watershed; consequently, the waters are of high quality. The lake is mesotrophic with moderate hydraulic detention times and thermal stratification patterns, but no significant algae problems.

b. Watershed Land Use. Drainage area at Tully dam includes 50 square miles, and is primarily wooded. Many swamps and marshes, a few small lakes, and relatively little open agricultural or pastoral lands occupy the remaining part of the watershed. The Corps leases 1,150 acres of the 1,310 acre reservoir area to the Massachusetts Department of Natural Resources for recreation, fish, wildlife, and forestry resources management. The remaining 160 acres of reservoir are reserved for normal project operation.

The Tully Lake watershed is rural with no industrial and relatively little residential or agricultural development. Royalston is the largest town within the watershed having a population of about 1,100. The Royalston State Forest, also located within the watershed, is not developed. No known point source discharges from industries or municipalities empty into rivers upstream from Tully Lake. Furthermore, since heavy residential and agricultural development are not prevalent in the drainage basin, the river is subject to few nonpoint source discharges due to runoff events.

c. Water Quality Conditions. The waters of Tully Lake are of good quality, often meeting or exceeding Massachusetts class B requirements. Water quality data collected at inflow and discharge stations through the NED sampling program since 1970 show consistently high dissolved oxygen, and low fecal coliform and turbidity levels. Minor areas of concern include low pH, and high color, iron, and manganese levels in these waters.

Examples of excellent water quality constituents at Tully Lake include high dissolved oxygen levels which almost always meet State standards, very low fecal coliform measurements which have not exceeded standards since monitoring began, and low turbidity measurements usually falling well below

10 JTU's which is the commonly accepted level at which water is still considered aesthetically pleasing. In addition, metals levels are fairly low and do not threaten human health or aquatic life.

Low to moderate nutrients levels have been measured at inflow and discharge stations at Tully Lake. Although phosphorus levels sometimes approach threshold concentrations capable of supporting algae blooms in an impoundment, nitrogen concentrations are usually well below these limits. Nuisance algae blooms have never been observed in Tully Lake, probably due to the low levels of nutrients found in these waters.

Mean pH levels usually fall short of the recommended 6.5 to 8.3 range, and the waters are somewhat acidic. High color and iron, and to a lesser degree, manganese levels are common in the waters of Tully Lake as well. Color, iron and manganese concentrations frequently exceed domestic water supply limits established by the EPA. These limits are set for aesthetic purposes and to prevent taste and laundry staining problems. Concentrations of color, iron and manganese present in these waters are not a health hazard to humans or aquatic life. These constituents originate from natural sources. Iron and manganese contribute to the high color of East Branch Tully River and its tributaries. Moreover, high color, iron and manganese and low pH levels found in the lake most likely originate from numerous swamps and marshlands in the watershed. Acid precipitation and poorly buffered New England soils further reduce pH levels.

d. Reservoir Conditions. Water temperatures in the lake and its tributaries provide good habitat for warm water fish species. These waters also provide a satisfactory cold water fish habitat until early summer when temperatures usually exceed 70° Fahrenheit. Based on the fairly warm water temperatures, low to moderate levels of nutrients and the absence of nuisance algae blooms, Tully lake most closely resembles a mesotrophic waterbody. A lake of this trophic status will rarely experience major algae blooms; however, occasional local blooms would be expected.

A recreation pool is maintained at elevation 641.0 feet NGVD from May until November, having a volume of 1,500 acre-feet. At this elevation, Tully Lake covers a surface area of about 305 acres to a maximum depth of 16.0 feet. Mean hydraulic residence times of 24, 32, and 26 days were calculated for July, August, and September, respectively. These are based on average monthly East Branch Tully River flows measured by the US Geological Survey for the period of record (1916 to 1990) at the gaging station near Athol, MA, located 300 feet downstream from the dam.

Lake profiling data were collected in 1982 at this project and incorporated in the June 1983 "Tully Lake Water Quality Evaluation" produced by NED. According to this study, Tully lake exhibits moderate thermally-induced density stratification patterns which form during the summer. This stratification often becomes weak or breaks up during high winds or on cool cloudy days, but forms again on warm sunny days. Dissolved oxygen measurements showed low to anaerobic levels in the hypolimnium indicating a lack of mixing of the waters. In addition, pH levels tended to decrease with depth as well. On the basis of one year's profiling work, the maximum surface to bottom temperature difference was 16°F observed on 12 July 1982, and the thermocline was located at a depth of about 5 feet.

4. WATER QUALITY REQUIREMENTS OF DROUGHT STORAGE

Two water quality requirements must be achieved for drought storage. The waters must meet State and Federal standards for surface waters and must be of a quality suitable for the water supply user. A water which meets class B standards in Massachusetts is usable for drinking water supply if standard treatment processes are used. Water quality requirements for industrial water supply depend on the process involved.

The Commonwealth of Massachusetts is the potential water supply user of drought storage at Tully Lake. At normal recreation pool capacity, the water is suitable for municipal or industrial use following standard treatment processes. In addition, these waters would be suitable for fire-fighting or irrigation without treatment.

5. EFFECTS OF INCREASED STORAGE ON NORMAL RESERVOIR WATER QUALITY

Drought contingency storage at Tully Lake would increase the pool 1.0 foot above the existing recreation pool to a water surface elevation of 642 feet NGVD (maximum depth of 17 feet) from July to November. This would increase the lake's volume from 1,500 to 1,825 acre-feet and surface area from 305 to 365 acres. Since very little water quality data during drought is available, the following discussion describes expected water quality changes due to additional storage based on normal flows at the project. Quality of water in the enlarged impoundment may degrade slightly due to the effects of newly inundated acreage, a deeper pool, and longer hydraulic residence times, but these changes would be fairly minor.

Inundation of vegetated lands when the pool is raised will affect water quality by causing a decay of organic material thereby releasing nutrients and metals to the overlying waters. This could lead to increases in color and suspended sediments, and, because of additional nutrients, a greater susceptibility to algae blooms. Raising the pool may also cause sloughing of sediments from wave action and during drawdown events. At Tully Lake, the shoreline is almost completely wooded, especially land at elevations higher than 642.0 feet NGVD. Most of the land between 641.0 and 642.0 feet NGVD is considerably less vegetated. Consequently, water quality degradation due to decay and erosion will probably be minor and localized.

Increased pool volume and depth strengthen stratification patterns, increasing extent and duration of anaerobic conditions in the lake. The proposed drought storage increases the overall volume by only 22 percent and increases in anaerobic conditions are expected to be minimal. Sediments in areas devoid of oxygen become chemically reduced causing iron, manganese, ammonia and phosphorus to become soluble and diffuse into the overlying waters. Ammonia levels also tend to rise under reduced dissolved oxygen conditions due to the reduction of nitrite and nitrate. Increases in the above constituents promote the potential for algae problems.

Enlarging the pool will also increase mean hydraulic residence times by 5 or 6 days to 29, 38, and 32 days for July, August, and September, respectively. Longer hydraulic residence times reduce flushing of the system which promotes warming of the waters. Warmer waters will strengthen thermal stratification patterns further increasing the severity of anaerobic conditions in the lake's bottom. Consequently, iron, manganese, ammonia, and phosphorus concentrations may increase somewhat in the waters of Tully Lake. Warmer water may slightly degrade the cold water fish habitat in the impoundment and downstream from the dam. Higher temperatures and nutrients concentrations can also cause algae problems, although, these are expected to be localized and nuisance blooms across the lake are not anticipated. Since mean detention times of the proposed impoundment would increase by only 5 or 6 days, water quality effects should be minimal with little change to the trophic status.

6. EFFECTS OF REDUCED FLOWS ON WATER QUALITY DURING DROUGHT

Drought storage is proposed at Tully Lake to supply additional water to downstream municipalities or industries in the event of a drought emergency. Drought storage would begin mid-spring, reaching the required 642 feet NGVD by July. The following paragraphs discuss how normal water quality could change as a result of reduced flows at the project during drought.

Droughts or long periods of low flow can have a pronounced effect on water quality. Reduced flows in streams are undesirable because stream temperatures tend to increase due to reduced depths and velocities, and dissolved oxygen levels tend to drop due to increased temperatures and reduced assimilative capacities. On the other hand, since no industries or municipalities discharge into Tully Lake's watershed, less fecal coliforms, nitrates and nitrites are washed into the rivers during droughts. As a result, these constituents may decrease during low flow periods in the East Branch Tully River. Overall, however, the undesirable effects of droughts outweigh any improvements in some water quality parameters.

In addition to the degraded water quality of its tributaries during drought conditions, decreased flows at Tully Lake will cause hydraulic detention times to increase significantly. Based on the minimum monthly East Branch Tully River flows for the period of record (1916-1990) at the gaging station near Athol, MA, maximum hydraulic detention times in the proposed drought storage pool for July, August, and September would be 350, 950, and 1,700 days, respectively. With these detention times, the lake would become virtually stagnant and associated water quality degradation caused by increased temperatures and more extreme stratification patterns can be expected.

Effects of drought on water quality, however, will occur regardless of the increase in pool size to accommodate drought storage. Maximum hydraulic detention times for the recreation pool alone during July, August, and September were estimated to be about 290, 780, and 1,400 days, respectively. At these levels, the lake will also experience almost complete stagnation and significant water quality degradation. Since maximum detention times for the proposed drought storage pool are not that much longer than those for the recreation pool alone, water quality degradation would be similar in nature, but somewhat more severe.

7. EFFECTS OF DROUGHT STORAGE OPERATIONS ON DOWNSTREAM WATER QUALITY

Under the present mode of operation, releases at Tully equal inflow except during flood storage periods when minimum outflow is limited to about 10 cfs. Under the drought contingency plan, filling of the drought storage pool would likely occur in May and June upon notification of a drought emergency. A minimum release of 7 cfs, the 7-day, 10-year experienced low flow (7Q10) calculated for the months of May through June, would be maintained during the filling operation. As a natural minimum flow of that season, this release should provide downstream water quality comparable with naturally experienced conditions. Small increases in temperature and decreases in dissolved oxygen would occur during filling, but probably not enough to impair aquatic habitat.

Once the pool reaches the drought storage elevation of 642.0 feet NGVD, reservoir releases would be maintained equal to inflow. Any minor water quality degradation would then be due to effects of increased storage as previously discussed. During drawdown of the drought storage pool (between July and October), minimum reservoir releases would augment natural inflow causing favorable effects on temperature, DO, water depth and velocity in the Tully Lake tailwater.

8. CONCLUSIONS

A pool increase from 641.0 to 642.0 feet NGVD during a drought emergency would have some effects on water quality; however, these effects would likely be minor. Water quality changes that can be expected at Tully Lake as a result of increased storage include higher water temperatures, lower dissolved oxygen levels, and increases in iron, manganese, ammonia, phosphorus, color and suspended solids. In consequence, the lake would be subject to a greater potential for the occurrence of localized algae blooms; however, severe algae blooms are not anticipated.

Since the water at Tully Lake has been historically of high quality, effects of drought storage should be minimal. Water temperatures may increase slightly, but probably not enough to impair cold water fish spawning and growth. Also, these waters are well cushioned against decreases in dissolved oxygen as levels are already quite high, and against increases in ammonia since levels are fairly low. Increases in iron, manganese, and color are not expected to be high enough to be harmful to humans or aquatic life. Also, increases in suspended sediment from the newly inundated lands should be localized and not significantly change overall water quality.

Unfortunately, lake waters tend to stagnate and most water quality conditions generally worsen during droughts.

This situation would happen during low flow periods regardless of drought storage. Drought storage releases made from the bottom of the pool using the flood control gates may help reduce stagnation. These low level releases should not alter downstream water quality since the water would become reoxygenated from turbulence within the outlet works. Drought storage releases would always be greater than or equal to inflow, except during the drought storage pool filling operation in the spring. During filling of the drought pool, the required minimum release would be the natural minimum 7Q10 flow of the May-June season. Consequently, downstream water quality degradation due to drought storage operations is expected to be minimal.

Standard treatment processes would be necessary to use the waters of Tully Lake for drinking water supply if drought storage were implemented. No treatment would be required for the water to be suitable for fire-fighting, irrigation, or various industrial processes.

APPENDIX D

SPONSORSHIP

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Protection

William F. Weld
Governor
Daniel S. Greenbaum
Commissioner

January 7, 1992

Mr. Richard D. Reardon
Corps of Engineers
424 Trapelo Rd.
Waltham, MA. 02254-9149

Dear Mr. Reardon:

I am responding to your letter of December 31, 1991. The Department of Environmental Protection is not interested in entering into a contract with the Corps for the purpose of utilizing Tully Lake as a source of emergency water supply. This decision is based on the work done by your staff and members of DEP staff which determined that the communities near Tully Lake were not interested in the opportunity. Without the local interest, the Department has no role to play.

I thank you for your time and effort on this matter.

Sincerely,

David Y. Terry, Director
Division of Water Supply

cc: Andrew Gottlieb, DWS
John Desmond, CERO
Kurt Boisjollie, WERO

One Winter Street • Boston, Massachusetts 02108 • FAX (617) 556-1049 • Telephone (617) 292-5500

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Protection

Daniel S. Greenbaum
Commissioner

August 12, 1991

Mr. Richard D. Reardon
Director of Engineering
Corps. of Engineers
424 Trapelo Road
Waltham, MA 02254-8149

Dear Mr. Reardon:

The Department of Environmental Protection would be interested in participating in the Drought Contingency Plan for Tully Lake. Initial investigation shows that it is unlikely that more than one or two communities would potentially benefit from the effort. Given that as well as present workloads, DEP participation will have to wait until early October.

If you feel that this remains a worthwhile venture, please let me know as I will serve as your initial contact.

Sincerely

Andrew Gottlieb, Manager
Water Management Program

cc: D. Terry
K. Boisjolie
J. Desmond

AG/hh
P/AG/hh/reardon

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